CHAPTER 5
HYDROLOGY

5.1 Introduction

5.1.1 Purpose

The analysis of the peak flow, volume of runoff, and time distribution of flow is fundamental to the design of storm water drainage facilities. Errors in the estimates can result in a structure that is either undersized and causes drainage problems or oversized and costs more than necessary. On the other hand, it must be realized that any hydrologic analysis is only an approximation. The relationship between the amount of precipitation on a drainage basin and the amount of runoff from the basin is complex, and too little data are available on the factors influencing the rural and urban rainfall-runoff relationship to expect exact solutions.

The purpose of this chapter is to describe approved methods of hydrological analysis for watershed studies and for the design of sediment ponds, stormwater best management practices, inlets, storm sewers, culverts, and channels.

5.1.2 Continuous Simulation as the Standard

LFUCG's approach is to manage both water quantity and water quality in a manner consistent with the development of new, more scientific techniques that take advantage of the computing power now available through the use of personal computers. The available computing power allows the use of continuous simulation models using actual historical rainfall events rather than the synthetic single-event storms currently used.

This chapter describes both currently approved single event models and continuous simulation models. The single event models can be used on an interim basis as the LFUCG moves toward the exclusive use of continuous simulation models.

5.2 Approved Methods

5.2.1 Single Event Modeling

Two models are approved for single event hydrologic modeling. They are the Corps of Engineers HEC-HMS program and the U.S. Environmental Protection Agency's Stormwater Management Model (SWMM). More information is given later on these models.

Other computer programs may be used for designing storm sewers, open channels, culverts, inlets, and detention ponds if they use the methods in this chapter for determining runoff hydrographs and peak flows.

5.2.2 Continuous Simulation

SWMM shall be the model used when conducting continuous simulations. The LFUCG will provide the Lexington rainfall record for use in such a simulation.

5.2.3 Rational Method

The Rational Method may be used to compute peak flows for drainage areas less than or equal to 25 acres when designing inlets, storm sewers, culverts, and channels.

5.3 Design Rainfall Event

5.3.1 Single Event Modeling

Stormwater facilities shall be designed using the design storms in Table 5-1. The design storm distributions are contained in Appendix 5A.

5.3.2 Continuous Simulation

The LFUCG will provide the rainfall record for continuous simulation.

TABLE 5- 1
APPLICATION OF DESIGN STORMS

Design Storm	Stormwater Facility						
	Floodplains	Detention Ponds[1]	Inlets	Storm Sewers	Culverts	Constructed Channels	Sediment Ponds[4]
1-year 1-hour						• [2]	
10-year 1-hour			•	•			
10-year 6-hour	•	•					•
10-year 24-hour							•
100-year 1-hour			•	•	• [3]	•	
100-year 6-hour		•					•
100-year 24-hour	•	•			• [3]		
June 18, 1992		•					
June 26, 1995		•					

1. Detention ponds shall be designed to reduce post-development peak flows to pre-development peak flows for the 10-year 6-hour, 100-year 6-hour, June 18, 1992, and June 26, 1995 storms. The emergency spillway shall be designed to pass the 100-year 24-hour storm.

2. Constructed channels in back yards and side yards of residential areas shall be designed with a paved trickle channel. The trickle channel shall be designed to carry 50% of the 1-year 1-hour storm.

3. The storm producing the largest peak flow shall be used to design culverts.

4. Sediment ponds shall be designed to:
   - remove 80% of total suspended solids for the 10-year 24-hour storm (or achieve a detention time of 24-48 hours)
   - reduce peak flows to pre-development levels for the 10-year 6-hour and 100-year 6-hour storms

5.4 HEC-HMS Model

5.4.1 Input Parameters

Runoff Volume

- The Green-Ampt method or Curve Number method may be used to determine the runoff volume.

- Green-Ampt soil parameters are shown in Table 5-2 for each soil group listed in the NRCS Soil Survey for Fayette County.

- Curve Numbers are based on the type of land use. Typical values are given in Table 5-3.

Unit Hydrograph

- The NRCS Unit Hydrograph Method shall be used. The time of concentration shall be determined using the method described in Technical Release No. 55 published by the U.S. Department of Agriculture, Natural Resources Conservation Service.

Storage Routing

- Use the stage-discharge-volume relationship for the structure.

Watershed Delineation

- Watersheds shall be subdivided into areas with homogenous land use. The subwatersheds shall have an average size of 10-50 acres, and a maximum size of 200 acres.

TABLE 5- 2
GREEN-AMPT INFILTRATION PARAMETERS
FOR FAYETTE COUNTY SOILS

NRCS Soil Series	NRCS Hydrologic Soil Group	Saturated Hydraulic Conductivity (inches/hour)	Wetting Front Suction (inches)	Initial Moisture Deficit (in/in)
Armour	B	0.20	6.6	0.17
Braxton	C	0.10	8.6	0.14
Captina	C	0.10	8.6	0.14
Culleoka	B	0.20	6.6	0.17
Donerail	C	0.10	8.6	0.14
Egam	C	0.10	8.6	0.14
Fairmount	D	0.03	12.5	0.08
Huntington	B	0.20	6.6	0.17
Lanton	D	0.03	12.5	0.08
Lawrence	C	0.10	8.6	0.14
Lindside	C	0.10	8.6	0.14
Loradale	C	0.10	8.6	0.14
Loudon	C	0.10	8.6	0.14
Lowell	C	0.10	8.6	0.14
Maury	B	0.20	6.6	0.17
McAfee	C	0.10	8.6	0.14
Melvin	D	0.03	12.5	0.08
Mercer	C	0.10	8.6	0.14
Newark	C	0.10	8.6	0.14
Russellville	C	0.10	8.6	0.14
Salvisa	C	0.10	8.6	0.14

For areas where there is no detailed NRCS soil survey, use the following values:

- Saturated Hydraulic Conductivity – 0.15
- Wetting Front Suction – 7.6
- Initial Moisture Deficit – 0.155

TABLE 5- 3
CURVE NUMBERS

Land Use	Percent Impervious	Hydrologic Soil Group			
		A	B	C	D
Urban Areas					
Parking Lots, Roofs, Driveways, and Streets	100	98	98	98	98
Commercial Development	85	89	92	94	95
Industrial Development	72	81	88	91	93
Residential Development:					
1/8 acre lots or less	65	77	85	90	92
1/4 acre lots	38	61	75	83	87
1/3 acre lots	30	57	72	81	86
1/2 acre lots	25	54	70	80	85
1 acre lots	20	51	68	79	84
Pervious Areas					
Lawns, Parks, Golf Courses, Cemeteries, etc.	-	39	61	74	80
Pasture for Grazing (not mowed)	-	39	61	74	80
Meadows (mowed for hay)	-	30	58	71	78
Brushy Areas	-	30	48	65	73
Woods	-	30	55	70	77

1. For urban areas that have a different percent impervious than those shown above, calculate a composite Curve Number using a Curve Number of 98 for impervious areas and the associated Curve Number for the pervious area from the table above.

2. For areas where there is no detailed NRCS Soil Survey, assume the subwatershed is 50% Group B soils and 50% Group C soils.

5.5 Stormwater Management Model (SWMM)

5.5.1 Input Parameters

Infiltration

- Green-Ampt soil parameters are shown in Table 5-2 for each soil group listed in the NRCS Soil Survey.

Overland Flow

- Use the values in Table 5-4 for N.

Depression Storage

- Impervious depression storage = 0.02 inches
- Pervious depression storage = 0.10 inches

Monthly Evaporation

- Use the values in Table 5-5.

Storage Routing

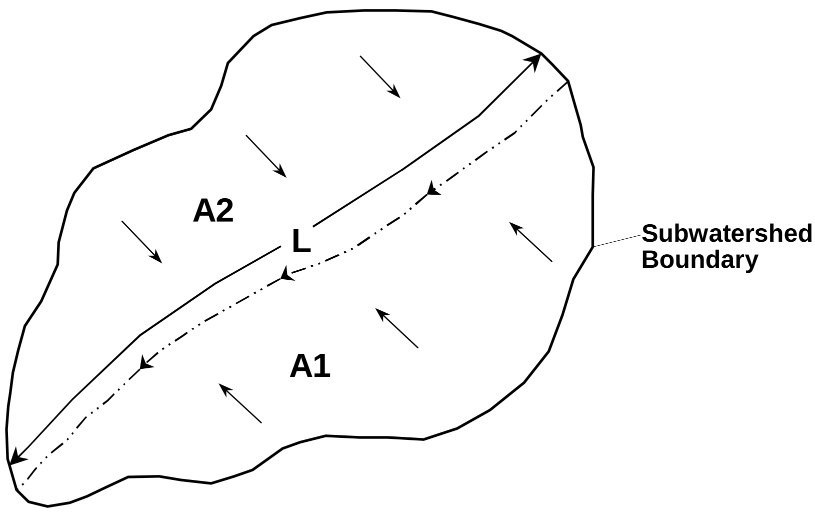
- Use the stage-discharge-volume relationship for the structure.

Watershed Delineation

- Watersheds shall be subdivided into areas with homogenous land use. The subwatersheds shall have an average size of 10-50 acres, and a maximum size of 200 acres.

5.5.2 Subwatershed Width Calculation

The following method shall be used to calculate the subwatershed width:



Subwatershed Width = W = (2 - S_k) x L

Where
S_k = skew factor ($0 \leq S_k \leq 1$) = (A2 - A1)/(A1 + A2)
A1 = Area on one side of the channel
A2 = Area on the other side of the channel
L = Length of the channel

TABLE 5- 4
MANNINGS N FOR OVERLAND FLOW

Surface	N
Asphalt or Concrete	0.015
Gravelled Surface	0.02
Short Grass Pasture	0.15
Dense Shrubbery and Forest Litter	0.40
Heavily Wooded	0.40
Bluegrass Sod	0.45

TABLE 5- 5
MONTHLY EVAPORATION RATES FOR FAYETTE COUNTY

Month	Inches / Month
January	1.31
February	1.52
March	2.97
April	3.83
May	5.23
June	6.71
July	6.96
August	6.62
September	4.97
October	3.55
November	2.14
December	1.39

5.6 Rational Method

The following equation may be used for drainage areas less than or equal to 25 acres.

Q = CIA

where:

Q = peak flow in cubic feet per second
C = 0.95 for impervious areas
    0.20 for pervious areas
A = drainage area
I = rainfall intensity

The rainfall intensity shall be determined based on Table 5-6:

TABLE 5- 6
TIME OF CONCENTRATION VERSUS RAINFALL INTENSITY

Time of Concentration (minutes)	Intensity (inches/hour)		
	1 yr.	10 yr.	100 yr.
10	3.2	5.3	6.9
15	2.8	4.4	5.7
30	1.9	3.1	4.2
60	1.2	2.0	2.9

The time of concentration shall be determined using the method described in Technical Release No. 55 published by the U.S. Department of Agriculture, Natural Resources Conservation Service. The minimum time of concentration shall be 10 minutes.

APPENDIX 5 A
DESIGN STORM DISTRIBUTIONS

1-HOUR RAINFALL DISTRIBUTIONS

Minutes	Cumulative Rainfall (Inches)		
	1 year	10-year	100-year
0	0.00	0.00	0.00
3	0.14	0.24	0.34
6	0.26	0.44	0.63
9	0.40	0.65	0.94
12	0.52	0.85	1.23
15	0.65	1.07	1.54
18	0.76	1.25	1.80
21	0.85	1.41	2.02
24	0.92	1.52	2.19
27	0.97	1.60	2.31
30	1.01	1.66	2.39
33	1.04	1.72	2.48
36	1.07	1.76	2.54
39	1.10	1.82	2.62
42	1.13	1.86	2.68
45	1.15	1.90	2.74
48	1.16	1.92	2.76
51	1.18	1.94	2.79
54	1.19	1.96	2.82
57	1.19	1.96	2.82
60	1.20	1.98	2.85

6-HOUR RAINFALL DISTRIBUTIONS

Minutes	Cumulative Rainfall (Inches)	
	10-year	**100-year**
0	0.00	0.00
20	0.10	0.16
40	0.24	0.36
60	0.37	0.57
80	0.59	0.90
100	0.86	1.32
120	1.15	1.76
140	1.47	2.26
160	1.81	2.79
180	2.09	3.22
200	2.32	3.58
220	2.51	3.87
240	2.65	4.08
260	2.76	4.25
280	2.85	4.38
300	2.93	4.51
320	2.97	4.58
340	3.01	4.63
360	3.07	4.73

10-YEAR – 24-HOUR RAINFALL DISTRIBUTION

Hours	10-year Cumulative Rainfall (Inches)	Hours	10-year Cumulative Rainfall (Inches)
0.0	0.00	12.5	3.21
0.5	0.02	13.0	3.38
1.0	0.05	13.5	3.49
1.5	0.07	14.0	3.58
2.0	0.10	14.5	3.66
2.5	0.12	15.0	3.73
3.0	0.15	15.5	3.79
3.5	0.18	16.0	3.85
4.0	0.21	16.5	3.90
4.5	0.24	17.0	3.94
5.0	0.28	17.5	3.98
5.5	0.31	18.0	4.02
6.0	0.35	18.5	4.06
6.5	0.39	19.0	4.10
7.0	0.43	19.5	4.13
7.5	0.48	20.0	4.16
8.0	0.53	20.5	4.19
8.5	0.58	21.0	4.22
9.0	0.64	21.5	4.25
9.5	0.71	22.0	4.27
10.0	0.79	22.5	4.30
10.5	0.89	23.0	4.32
11.0	1.03	23.5	4.35
11.5	1.24	24.0	4.37
12.0	2.90		

100-YEAR – 24-HOUR RAINFALL DISTRIBUTION

Hours	100-year Cumulative Rainfall (Inches)	Hours	100-year Cumulative Rainfall (Inches)
0.0	0.00	12.5	5.01
0.5	0.04	13.0	5.26
1.0	0.07	13.5	5.44
1.5	0.11	14.0	5.58
2.0	0.15	14.5	5.71
2.5	0.19	15.0	5.81
3.0	0.24	15.5	5.91
3.5	0.28	16.0	5.99
4.0	0.33	16.5	6.07
4.5	0.38	17.0	6.14
5.0	0.43	17.5	6.21
5.5	0.48	18.0	6.27
6.0	0.54	18.5	6.33
6.5	0.60	19.0	6.38
7.0	0.67	19.5	6.43
7.5	0.74	20.0	6.48
8.0	0.82	20.5	6.53
8.5	0.90	21.0	6.57
9.0	1.00	21.5	6.62
9.5	1.11	22.0	6.66
10.0	1.23	22.5	6.70
10.5	1.39	23.0	6.74
11.0	1.60	23.5	6.77
11.5	1.93	24.0	6.81
12.0	4.52		

HISTORIC RAINFALL DISTRIBUTIONS

Minutes	Cumulative Rainfall (Inches)	
	June 18, 1992	June 26, 1995
0	0.00	0.00
20	0.01	0.03
40	0.03	0.11
60	0.05	0.25
80	0.07	0.60
100	0.08	1.36
120	0.08	2.05
140	0.08	2.43
160	0.08	2.70
180	0.08	2.95
200	0.08	3.57
220	0.08	4.03
240	0.08	4.20
260	0.08	4.23
280	0.08	4.24
300	0.09	4.25
320	0.55	
340	1.73	
360	2.24	
380	2.28	
400	2.31	
420	2.32	
440	2.32	
460	2.32	
480	2.32	
500	2.32	
520	2.32	
540	2.32	
560	2.32	
580	2.32	
600	2.32	
620	2.32	
640	2.32	
660	2.32	
680	2.32	
700	2.32	
720	2.32	
740	2.32	
760	2.32	
780	2.32	
800	2.32	
820	2.32	
840	2.32	
860	2.38	
880	2.56	
900	2.87	
920	3.49	
940	4.37	
960	4.69	
980	4.72	
1000	4.74	
1020	4.74	
1040	4.82	
1060	4.94	
1080	4.99	